SUMMARY OF MODEL-SUPPORT INTERFERENCE PROBLEMS

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ABSTRACT

Lately, an increasing amount of attention is being given to aerodynamic measurements which can be materially affected by the base flow conditions. Examples of such measurements are: total drag of slender bodies, trim angle of blunt bodies, dynamic stability in pitch, base pressure and heating, and wake properties. In many instances of model testing, the measurements of certain aerodynamic characteristics are not applicable to the actual flight conditions of interference-free flow. Although the existence of the support-interference problem is general knowledge, this would be a good opportunity to remind everyone of its importance as data have been released recently which may be in error due to support-interference.

INTRODUCTION

It is not the intent of this paper to go into the subject of support-interference problems, but rather to emphasize that such problems generally exist during conventional "captive" tests. The usual evaluation of the data from such tests tends toward the assumption that support-interference is negligible. This is not the conservative approach. In all cases of such testing, it is imperative that the effects of support-interference on the data be considered substantial until shown to be otherwise. For the purpose of illustrating the possible existence of support interference, a fairly complete discussion on the effects of small wire supports upon the wake separation region follows. This illustration should point out that one should not arbitrarily rule out the presence of support-interference effects until it has been conclusively shown that they are negligible.

DISCUSSION

As it is generally recognized that the presence of a sting, no matter how feasibly small, is likely to affect base pressure and base heating, the use of side-mounted or wire-supported models is usually relied upon in order to obtain essentially disturbance-free measurements in the base region. During the development of the free-flight testing technique in the Jet Propulsion Laboratory (JPL) continuous wind tunnels (Ref. 1), it was observed that the small diameter wires (used to support the models prior to their free-flight trajectories) usually had a significant effect upon the shape of the wake separation region. This serves to demonstrate that the use of either side-mounts or wires to support a model in order to obtain interference-free base region measurements is not necessarily an adequate approach.

Concurrent with the acquisition of free-flight model-wake spark-schlieren pictures (Ref. 2), interference effects of small diameter wire supports (0 to 3% of model diameter) upon the separation region shape was investigated for spheres and various cone models through the Mach number (M) range from $M = 1.3$ to $M = 5$ and for several cones at $M = 9$. The presence of a single traverse vertical wire support did noticeably alter the sphere separation region shape at $1.3 < M < 5$. Spark schlieren pictures at $M = 3$ in Fig. 1a indicate this typical interference effect. As the diameter of the vertical wire was increased from 0 (free-flight) to 0.040 in., the position of the wake neck moved toward the sphere. Figure 1b is a graphical presentation of this wake interference phenomenon at several Reynolds numbers; the definition of the characteristic wake length, L, being shown in Fig. 1c. From these results it appears that any wire capable of supporting a sphere will alter the wake.

In Fig. 1a the schlieren pictures indicate that the flow field in the plane of the wire support has no obvious major disturbance due to the wire. As can be seen in Fig. 2, the flow field in the plane normal to the wire support is severely disturbed by the presence of the wire. Hence, it is not surprising that a seemingly insignificant wire support can materially alter the wake shape.

A similar interference investigation was carried out for 30-deg included-angle cones at $1.6 < M < 4.7$. At $M \leq 2$, there did not appear to be a strong effect of the support wire (about 2% of the cone diameter) on the shape of the separation region for the high Reynolds number condition (Fig. 3a). But at the lower Reynolds numbers ($< 2 \times 10^5$) when the wake was definitely laminar to beyond the neck region, the presence of the wire support did decrease the distance of the wake neck to the model. However, at $M > 2$, the effect of the wire support was quite pronounced at high as well as at low Reynolds numbers; a typical example at M = 4.7 being shown in Fig. 3b. As in the case of the sphere, the presence of the wire support moved the wake neck toward the cone base. Investigations at M = 9 in the JPL 21-in. hypersonic wind tunnel show that the normally convergent wakes of free-flight cone models become divergent when the 1 1/2-in. diameter models are supported on a single traverse 0.024-in. diameter wire.

Sketchy experimental evidence indicates that when the model boundary layer is turbulent, the presence of a wire support does not materially alter the shape of the wake separation region. This has been observed at M = 4 for blunted cones of nose radius to base radius ratios of 0.05 and 0.50. At M = 1.6 and M = 2, when the wire support did not alter the wake separation region of the 30-deg apex angle cone, the shape of the separation region of these models was the same whether or not the model boundary layer was laminar or turbulent (obtained by tripping the boundary layer).

A further word of caution pertains to outside disturbances in the wake which may propagate forward to the model base region. Even for free-flight models, an object in the wake or a shock-wave (reflected model bow shock or from some other source such as a sabot) intersecting the wake, not far enough downstream of the model, may alter the base region flow field. Drag coefficients of spheres were measured during the work described in Ref. 1. At M = 1.3 when a 1 1/2-in. diameter sphere was used in the JPL 20-in. supersonic wind tunnel, the bow shock intersected the wake about two diameters downstream from the base. This interference caused a 4% decrease in the measured drag coefficient relative to ballistic range data. When the bow shock intersected the wake five or more diameters from the base, the measured drag coefficients were within 1% of ballistic range data. A similar decrease in the drag coefficient has been observed on sting-mounted spheres (Ref. 3, Appendix), when the bow shock wave intersects the wake too near the model.

From the support-wire wake-interference studies, it has been shown that such a manner of supporting models is likely to cause incorrect base flow conditions. Even if it is suspected that a wire support, or some other seemingly negligible support, will not alter the model base flow under the particular conditions being investigated, this should be demonstrated to be the case and not just be assumed. Also, any outside disturbance in the wake must be kept far enough downstream, in order that it does not propagate forward to the model and alter the base region flow field.

REFERENCES

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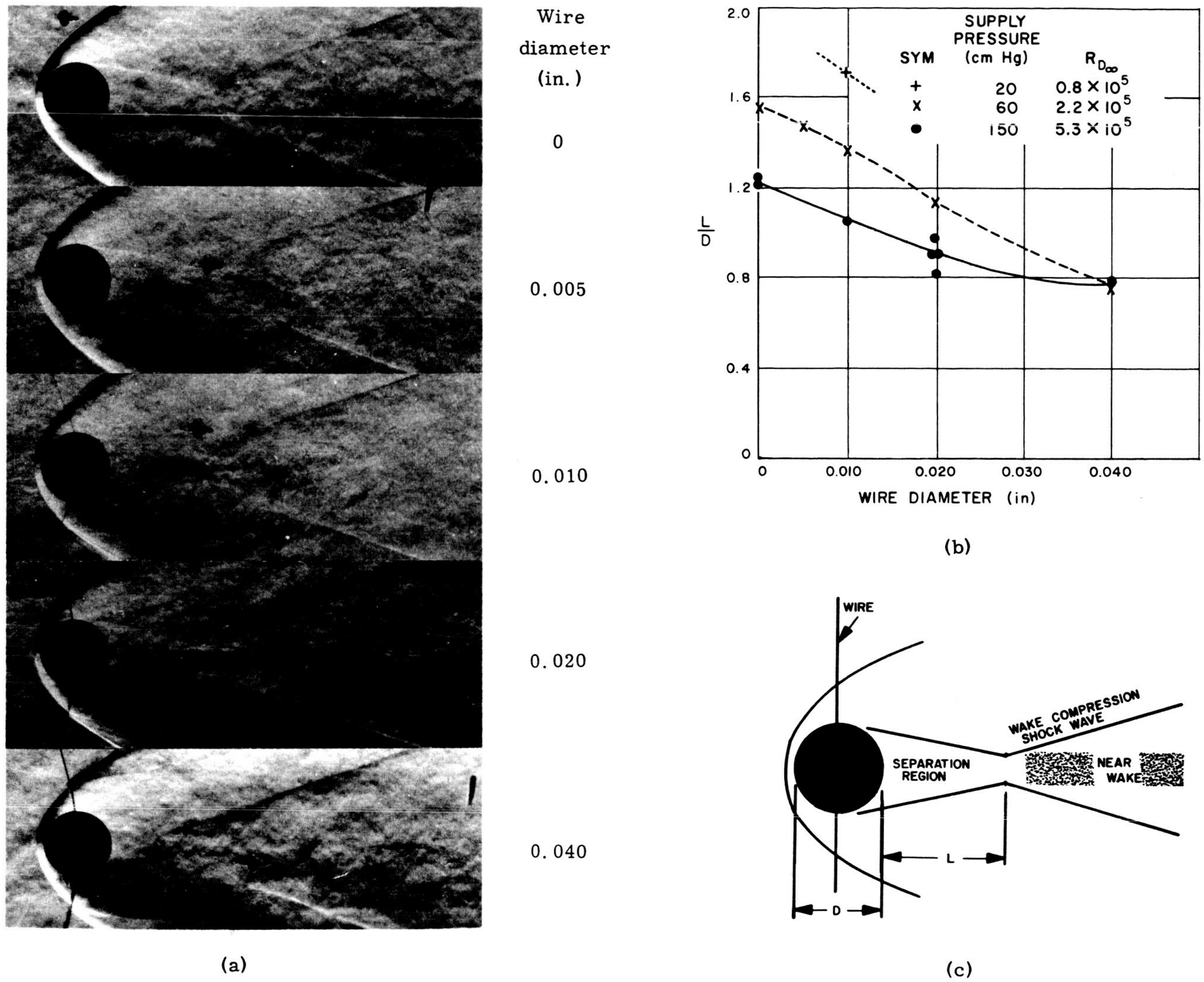
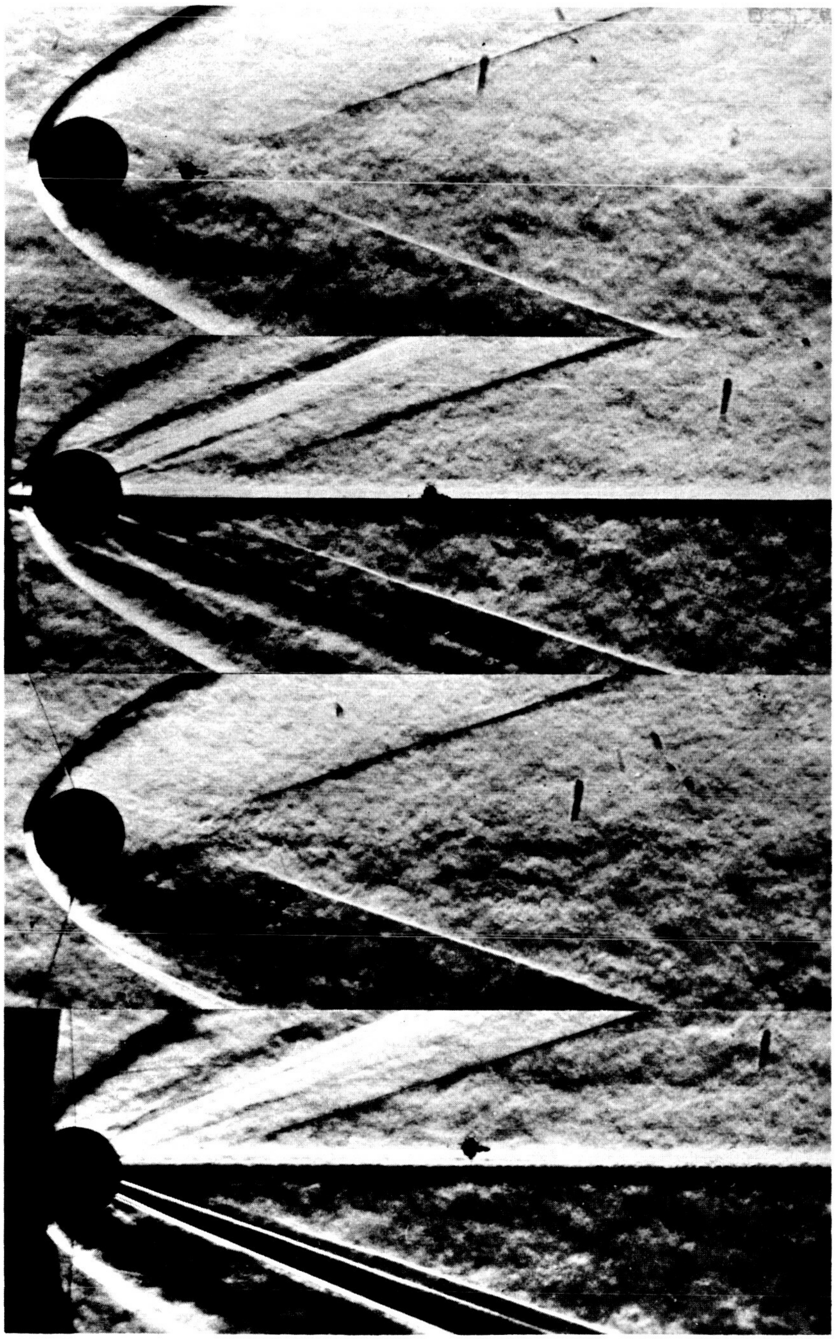


M = 3

Supply pressure = 60 cm Hg
$R_{D\infty} = 2.2 \times 10^5$
Model diameter = 1 1/2 in.

Fig. 1. Effect of diameter of vertical wire support on sphere wakes



Wire orientation

No wire

Horizontal

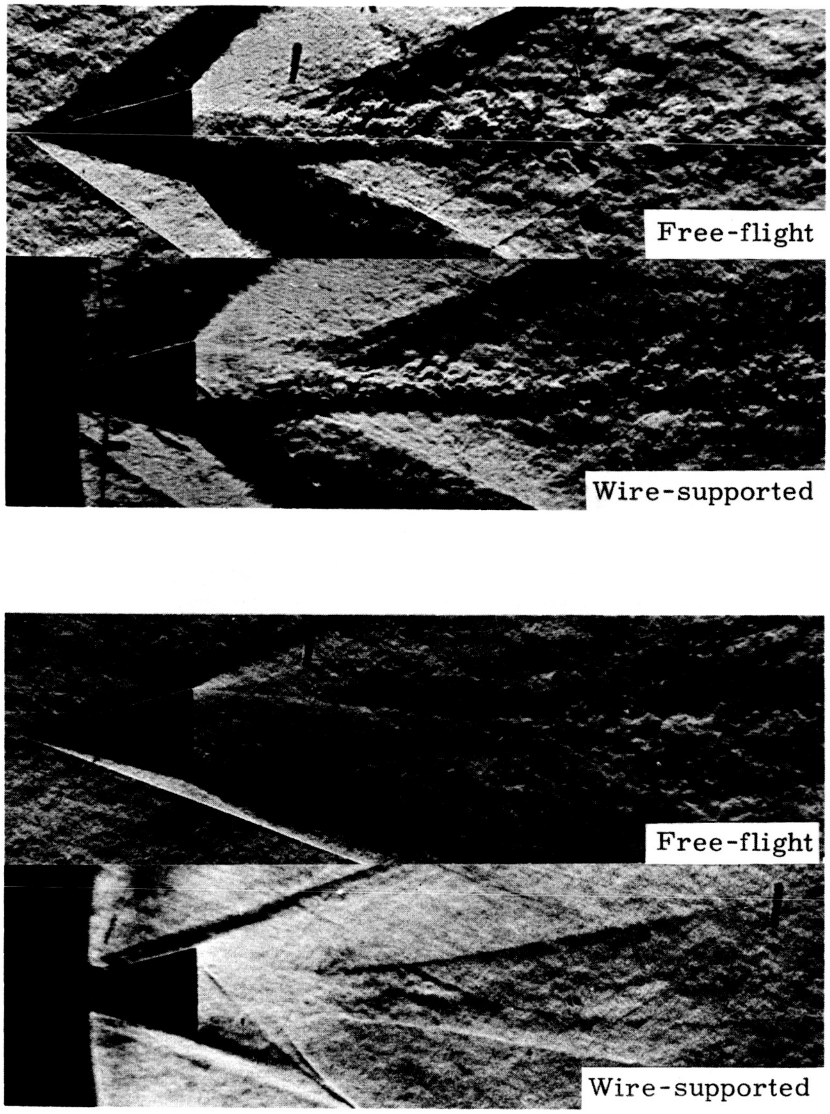
Vertical

Both horizontal and vertical

M = 3

Supply pressure = 150 cm Hg
$R_{D\infty} = 5.3 \times 10^5$
Model diameter = 1 1/2 in.
Wire diameter = 0.020 in.

Fig. 2. Effect of support wire orientation on sphere wakes



(a)

M = 2.0

Supply pressure = 140 cm Hg

$R_{D_\infty} = 8 \times 10^5$

(b)

M = 4.7

Supply pressure = 330 cm Hg

$R_{D_\infty} = 4.5 \times 10^5$

30-deg apex angle
Model diameter = 1 1/2 in.
Wire diameter = 0.026 in.

Fig. 3. Effect of wire support on cone wakes